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Testing for errors in estimating bird mortality rates at wind farms and power lines

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Running title: Mortality rates and scavengers

Abstract

Wind power, as an alternative to fossil fuels, is increasingly more common, and is expanding worldwide. One of the main adverse impacts of wind farms is the mortality of flying animals through collision with moving rotor blades and from electrocutions on associated power lines. Avian mortality rates have been estimated for wind farms from birds collected under turbines over varying time intervals. However, scavengers may cause an underestimation of fatalities, if dead birds are not monitored more frequently. In this paper, we test experimentally, possible errors arising in the estimation of avian mortality rates at wind farms and power lines caused by carcass removal by scavengers. We used pigeon and quail carcasses placed under wind turbines of two different wind farms and associated power line in South Spain to determine the disappearance rate (in days) of dead birds by scavengers. Distances that carcasses were taken by scavengers were determined by radio-tagging all dead pigeons. We found significant statistical differences in carcass disappearance rates between pigeons and quails and between wind farms and power lines. However, there were no significant differences in disappearance rates between habitats for pigeons or for quails. Only 40% of remain carcasses was found at a distance less than 100 m from the points in which they were deposited. The 100% and 45% disappearance rate of quails and pigeons were on the third day and on the fourteenth day, respectively. Taking into account that scavenging losses is wind farm and power line specific we propose a method to correct the estimation of the number of kills that could be replicated in any wind farm and power line. By doing this, we can improve our understanding of the real impact of wind structures on adjacent bird communities and adopt appropriate measures to ensure their conservation.

Key-words: bird mortality, carcass persistence, pigeon, power line, quail, scavenger removal, southern Spain, wind farm.

Introduction

Wind farms consist of numerous individual wind turbines that are connected to the electric power transmission network. Since the 1980s wind farms have become an economically attractive energy option (ITDG 2005), often receiving substantial governmental support in many countries (Carrete et al. 2009). As a result, wind farms have proliferated worldwide and this trend is expected to continue (Ledec et al. 2011). In Spain, the proliferation of wind farms has been unprecedented; the country is now the fifth producer of wind energy in the world with an installed capacity of 22,988 MW distributed in 1,077 wind farms at the end of the year 2015 (http://www.aeeolica.org). Because the country is an important migration flyway for many birds between Europe and Africa, the potential negative impact of wind farms on these needs particular study.

Wind farms cause negative environmental impacts on the landscape and on birds and bats (May et al. 2015, Peste et al. 2015). The most obvious effect on birds is deaths caused by collisions and electrocutions (Drewitt and Langston 2008, Lucas et al. 2012). Wind power can also affect birds by displacing them from their nesting sites, foraging areas, daily transit or migration routes (Drewitt and Langston 2006). Death through collision can be substantial for some species and populations may be negatively impacted (Johnson et al. 2002). Long-lived species, such as vultures, eagles and other birds of prey, are more prone to undergo population declines if collision mortality increases (Carrete et al. 2009, Sanz-Aguiar et al. 2015).

To evaluate the impact on birds of wind farms and power lines post-construction, environmental authorities generally require wind developers to monitor sites for one or two years after the start of operations. Although monitoring may vary according to area, commonly, bird mortality is estimated by directly counting avian collisions or body counts. There is no specific legislation determining the frequency of monitoring to estimate bird mortality in wind farms and power lines and this aspect is determined by the environmental authorities for each individual case. Carcasses are usually counted at 1-2 week intervals within a radius of 50-100 m around turbines or under power lines (Ferrer et al. 1991, Osborn et al. 2000, Lucas et al. 2004, Drewitt and Langston 2008, Farfán et al. 2009, Lasch et al. 2010). There is no scientific evidence supporting this monitoring frequency and monitoring surface.

Studies usually report relatively low bird mortality rates around wind farms and power lines (Alonso and Alonso 1999, Erickson et al. 2001, Langston and Pullan 2003, Percival 2005, Farfán et al. 2009, Gue et al. 2013). Such impact levels may be an artefact of a mismatch between the location of wind farms and power lines and bird concentrations (Carrete et al. 2012). But, it may also be a result of the relatively low coverage of sites. Moreover, studies often report body counts without taking into account habitat differences in carcass detectability, search efficiency, search effort, or removal of carcasses by scavengers (Scott et al.1972, Morrison 2002, Erickson et al. 2005, Smallwood 2007, Drewitt and Langston 2008, Carrete et al. 2009). However, these factors are sources of error and variation in power lines and wind farm bird mortality studies (Gehring et al. 2009, Longcore et al. 2012). Specifically, carcass removal by scavengers is likely to give rise to considerable bias in bird mortality estimates since removal of carrion is quick and prevalent in most habitats (Kostecke et al. 2001,Prosser et al. 2008, Ponce et al. 2010, Smallwood et al. 2010). In particular, if the time interval between carcass searches is more than the permanence of a carcass in an area, then observers will only detect a small percentage of these.

Some authors have investigated persistence of carcasses under wind farms or power lines. Ferrer et al. (1991) tested this by using rabbit carcasses (Oryctolagus cuniculus L.) placed under pylons and power lines. These authors showed that 70% of carcasses had disappeared one month after placement. Lucas et al. (2008) also indicated that carcasses of large birds, equivalent in size or larger than a black kite (Milvus migrans L.), could remain for months or even years untouched by scavengers. However, there are limited data for small to medium-size birds, such as kestrels, pigeons, or small passerines (Drewitt and Langston 2008).

In this paper, we present a useful methodology to correct potential errors arising in the estimation of avian mortality rates at wind farms and power lines caused by carcass removal by scavengers. We examine the removal by scavengers of pigeon (representing medium-sized birds) and quail carcasses (representing small birds) at wind farms and power lines in southern Spain. We quantified rates of permanence of the two different sized birds, and develop a metric for estimating the mortality rate of stricken birds by species. In addition, we radio-tagged carcasses to calculate dispersal distances caused by scavengers.

Materials and methods

STUDY AREA

The study wind farms, “Puerto de Malaga” and “Sierra de Baños”, and their associated power line, are located in Malaga province, southern Spain (UTM 30SUF38). These wind farms are contiguous, situated on a W-E running mountain ridge. There are 13 wind turbines, evenly distributed along a continuous row, at elevations ranging from 555 m and 727 m above sea level. Wind turbines are placed about 150 m apart; total length 1,800 m. The power line is located along the westernmost part of the wind farms and run N-S; total length 23,000 m. We studied the 5-km stretch nearest the wind farms (Figure 1).

Figure 1

Vegetation in the study area is dominated by Mediterranean-type scrubland. The most representative species are Phlomis purpurea Linnaeus, Phlomis lychnitis Linnaeus, Quercus coccifera Linnaeus, Chamaerops humilis Linnaeus, Rosmarinus officinalis Linnaeus, Cistus albidus Linnaeus, and Ulex parviflorus Pourret. Along the eastern portion of the wind farms there are also scattered Aleppo pine trees (Pinus halepensis Miller), while in the lower western area, scrubland is mixed with cereals and olive groves.

The vertebrate community in the study area is represented by several bird and mammal species (Martí and Del Moral 2003; Palomo et al. 2007). The main scavengers are Common Raven (Corvus corax), red fox (Vulpes vulpes) and Egyptian mongoose (Herpestes ichneumon) though feral cats and dogs are also very common in the study area (pers. obs.).

FIELD METHODS

We determined carcass removal rates by scavengers between May and September 2009. We placed a total of 57 bird carcasses [22 pigeons (Columba livia f. domestica) and 35 quails (Coturnix coturnix)] at the wind farms, and along the 5 km associated power line in nine different series (Table 1). All carcasses were placed between 8 and 10 in the morning. At the wind farms, carcasses were randomly placed around a maximum radius of 70 m from the wind turbines but under pylons and power lines carcasses were randomly distributed. Bird carcasses were spread far apart to avoid an increase in removals caused by higher carcass density (Bevanger et al. 1994, Stevens et al. 2011). We also placed carcasses in the two different habitats present in the study area: crops and scrubland. As recommended by Smallwood (2007) all carcasses were inspected daily. We estimated the Kaplan-Meier product limits to measure the disappearance rate of carcasses (White and Garrott 1990).

Table 1.

Distances that carcasses were taken by scavengers were determined by radio-tagging all dead pigeons with 27-g TW 3 brass collar transmitters (Biotrack, UK). Radio-tagged birds were located using a GPS eTrex Vista Cx (Garmin, USA), a portable Yagi-antenna, and a Yaesu VR-500 receiver (Wagener Telemetrie, Germany). We used the homing-in technique as the standard procedure for all locations (White and Garrott 1990). We calculated the dispersal distance (in metres) of each carcass as the distance between the point where the carcass was placed to the point where it was discovered or radio transmitters found. These results allow us to know if there is a high or low probability to find the remains of corpses in the usually surveyed surface once scavengers have eaten the carcass.

STATISTICAL APPROACH

We used a GLM with Poisson error distribution and a log-link function model (Crawley 1993) to analyze whether factors, experimental carcass, i.e. type of carcass (quails vs pigeons), the habitat available (crops vs scrubland) and the placement site (wind-power plant vs power line) affected the permanence time (in days) -the dependent variable-.

All mean values of analyzed parameters are given with their standard error.

To calculate the mortality rate linked to the studied wind farms and associated power line, we employed the following equation:

$$EMR = \frac{OCB}{ED} \quad (1)$$

where EMR is the estimated daily mortality rate, OCB is the observed number of carcasses, and ED is the number of equivalent days, i.e. the number of days in which the collision of birds yielded the observed carcasses if the disappearance rate was zero. ED was calculated adding the proportion of daily persistence for quail and pigeon carcasses, respectively.

From equation (1) it follows that estimated mortality during a specific period of time results from EMR multiplied by any number of days between successive monitoring days.

BIAS IN ESTIMATING BIRD MORTALITY

We used disappearance rate and dispersal distances of pigeons obtained in this study to show that current monitoring schemes undertaken by the environmental authorities, at a frequency of 1-2 weeks and over a surface of 50-100 m, may underestimate mortalities of medium-sized birds.

Results

Radio-tagging revealed that only 40% of the deposited carcasses was found at a distance of <100 m from the points in which they were placed, while most carcasses (60%) were taken distances of >100 m.

The GLM model showed a high fit to the Poisson distribution (0.931) and had an acceptable percentage of deviance explained (71.4%). The model revealed that variables with the highest explanatory power within the model (highest Wald statistic values) were experimental carcasses and the placing site (Table 2). Both variables had a significant effect on the permanence time whereas the habitat did not. Permanence time was positively affected by experimental carcass type, being higher for pigeon than quail carcasses (pigeons: 4.6 ± 0.7 days; quails: 1.5 ± 0.3 days). The placement site also negatively affected permanence time. Permanence was lower in the wind-power plant than in the power line regardless of experimental carcass type (wind-power plant: pigeons: 4.1 ± 1.1 days and quails: 1.0 ± 0.3 days; power line: pigeons: 5.1 ± 1.0 days and quails: 2.1 ± 0.5 days).

Table 2

The disappearance rate of quails was 55% on the first day, 85% on the second day, and 100% on the third day. Disappearance rate was slower for pigeons, 10% on the three first days and 45% until fourteenth day (Figure 2).

Figure 2

Using the disappearance rates for quails and pigeons, the daily mortality rate was estimated as:

1. - Quails:

ED_{quails} = 1.00 + 0.45 + 0.16 = 1.61

$$EMR = \frac{OCB}{1.61}$$

2. - Pigeons:

$ED_{pigeons}$ = 1.00 + 0.89 + 0.89 + 0.89 + 0.55 + 0.55 +0.55 +0.55 +0.55 +0.55 + 0.55 = 7.52

$$EMR = \frac{OCB}{.52}$$

At both 7 and 14 days the proportion of pigeons remaining in the sites where they were deposited was 55% (12 carcasses) but the remaining 45% (10 carcasses) were dispersed by scavengers. Scavengers displaced three carcasses <50 m, and one other to a distance of 50 - 100 m. Monitoring with a frequency of 7-14 days and a sampled surface area of 50 and 100 m underestimated bird mortality by 31.8% and 27.3%, respectively.

Discussion

Most previous studies on the impact of wind farms on birds have been conducted to assess the most obvious effect of wind farms on birds, mortality caused by collisions, but limited to recording species found dead under turbine blades (Martínez-Abrain et al. 2012). Small birds and bats may have been overlooked in previous carcass searches (Kunz et al. 2007) due to cryptic coloration, small body size, steep topography, or thick vegetation, among other factors. The practice of collecting dead birds and those injured by collisions at wind farms is considered to underestimate fatalities due to air currents blowing carcasses away from the collision site, and to an unknown impact of scavengers removing carcasses (Desholm et al. 2006).

We show in this paper, that the reported low mortality rates currently used to dispel any concerns about wind energy may be seriously biased due to the removal of carcasses by scavengers. We demonstrate that, at least in spring and summer, the disappearance rate of dead animals is greater than the search intervals proposed usually by environmental authorities (periods of 7-14 days), hence the recommended monitoring will underestimate the number of dead animals. Our results, alongside those of other authors suggest that scavengers remove carcasses in a few days. For example, Prosser et al. (2008) found removal rates of up to 32% (winter) and 91% (summer) within four days of placement, and Kostecke et al. (2001) found scavenging rates of up to 66% within five days. Similarly, Ponce et al. (2010) showed that up to 66.7% of small birds (represented by quails) and 85.7% of very small birds (represented by quail halves) were removed two days after placement. Smallwood et al. (2010) found scavengers removed 0% and 67% of large-bodied raptor carcasses in winter and summer respectively, within a period of 15 days. Finally, Urquhart et al. (2015) showed that 85% of Buzzard (Buteo buteo) carcasses remained for a period of 95 days. These results show that the recommended monitoring period of 7-14 days for carcass search surveys is insufficient, especially when recording the impact of small-sized birds. We show in our study that scavengers remove quails (representing small birds) faster than they remove pigeons (representing medium-size birds). Other authors have also found that scavengers remove small birds in very short periods of time (Kerlinger et al. 2000, Lekuona and Ursúa 2007, Ponce et al. 2010, Stevens et al. 2011), while raptor carcasses persist longer than non-raptors (Smallwood, 2007; Urquhart et al., 2015).

Lower permanence of the experimental carcasses in the wind-power plants than in the power line obtained in this study can be explained by the differential abundance of scavengers at both sites. Feral cats and dogs are more frequent in the wind farms (pers. obs.), although we have not done specific analysis to determine significant differences in abundance and our results could be due to this factor and others different.

Our results show that there was a high proportion of carcasses dispersed at distances of >100 m. These observations suggests that it is highly unlikely for monitors employed by environmental authorities to discover dead animals within the currently used radius of 50-100 m around turbines and power lines. We argue that the current procedure will underestimate bird mortality by wind farms and power lines.

This study also shows that monitoring bird mortality every 7-14 days and around a 50-100 m radius will underestimate medium-sized bird mortality, as shown by our pigeon data. Although we did not radio-tagged quails, representing small birds, the disappearance rate indicates that for quails, monitoring every 7-14 days and within a 50-100 m radius, severely underestimates small bird mortality.

Most research on fatalities at onshore wind farms and power lines rely on carcass searches, but because this method is limited it has to be assumed that the number of carcasses reported represents only a minimum number of actual fatalities (Drewitt and Langston 2008). If this is the case, and we also take into account that wind farms and associated power lines have proliferated worldwide, then there is a pressing need to improve the methods used in fatality studies, determine the real impact of these structures on flying fauna and ensure the conservation of the most vulnerable species.

We argue strongly that a key challenge in wildlife mortality surveys is, among other factors, the control of errors caused by not taking into account the impact of scavengers and the development of protocols to minimize bias. Taking into account that scavenging losses is wind farm and power line specific, a first step would be to correct the estimation of the number of fatalities at each wind farm and associated power line. In the present study we propose a method to do it that could be replicated in any wind farm and power line differing in habitats, bird communities and scavenger communities. If the correction of the number of fatalities were not applied, increasing search efforts could minimize biases. Environmental authorities must demand shorter periods for search surveys as the current recommended period of 7-14 days is clearly insufficient. As we discussed above, scavenging losses is wind farm and power line specific but it is generalised that persistence of small and medium size non-raptor birds is shortest. Thus, according to our results, and in line with Kostecke et al. (2001), we consider it reasonable to recommend that in spring and summer, when a higher proportion of carcasses are likely to be removed by scavengers (Prosser et al. 2008, Ponce et al. 2010), carcass searches should be undertaken daily for small birds and in periods of three days for medium-sized birds. This frequency of carcass search will improve the estimates of mortality especially for small and medium-sized non-raptors.

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Table legends

Table 1. Distribution of pigeons and quails placed in the two wind farms and power line. The date and habitat used in the nine series are shown.

Table 2. Results of the GLM model analysing factors affecting the permanence time (in days) of two types of carcasses. P values are considered significant at $P < 0.05$ while ns refer to non-significant values. Factors included in the model were type of carcass (1, pigeon or 2, quail), type of placing site (1, wind-power plant or 2, power line) and type of habitat (1, crops or 2, scrubland).

Table 1

Date	Pigeons		Quails		Habitat
	Wind farm	Power line	Wind farm	Power line	
19/05/2009		3			crop (3)
01/06/2009		3			scrubland (3)
11/06/2009		4			crop (2), scrubland (2)
06/07/2009	6				crop (4), scrubland (2)
14/07/2009	4				crop (1), scrubland (3)
04/08/2009	2				scrubland (2)
24/08/2009			5	5	crop (4), scrubland (6)
07/09/2009			7	8	crop (7), scrubland (8)
25/09/2009			5	5	crop (5), scrubland (5)

Table 2

Source of variation	B ± SE	d.f.	Wald	P
Experimental carcass	1.099 ± 0.1697	1	41.950	< 0.001
Placing site	-0.402 ±01693	1	5.627	0.018
Habitat	0.054 ± 0.1693	1	0.102	0.749

Figure legends

Figure 1. Location of the study area. X: geographic reference (36º 51' 9''N; 4º 49' 12''W)

Figure 2. Kaplan-Meier disappearance functions for pigeon and quail carcasses experimentally deposited under wind farms and power line in the study area.

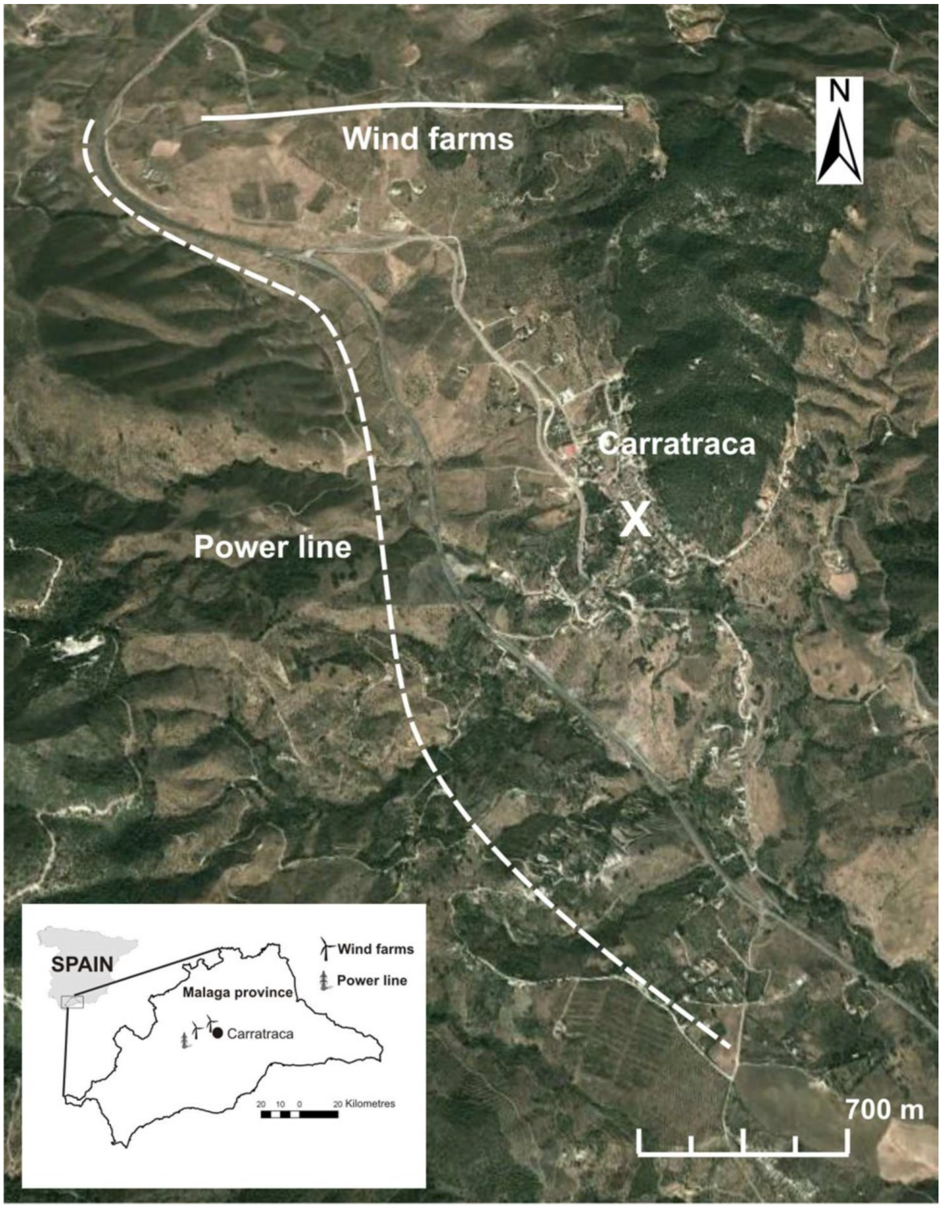

Figure 1. Location of the study area. X: geographic reference (36º 51' 9''N; 4º 49' 12''W)
93x119mm (300 x 300 DPI)

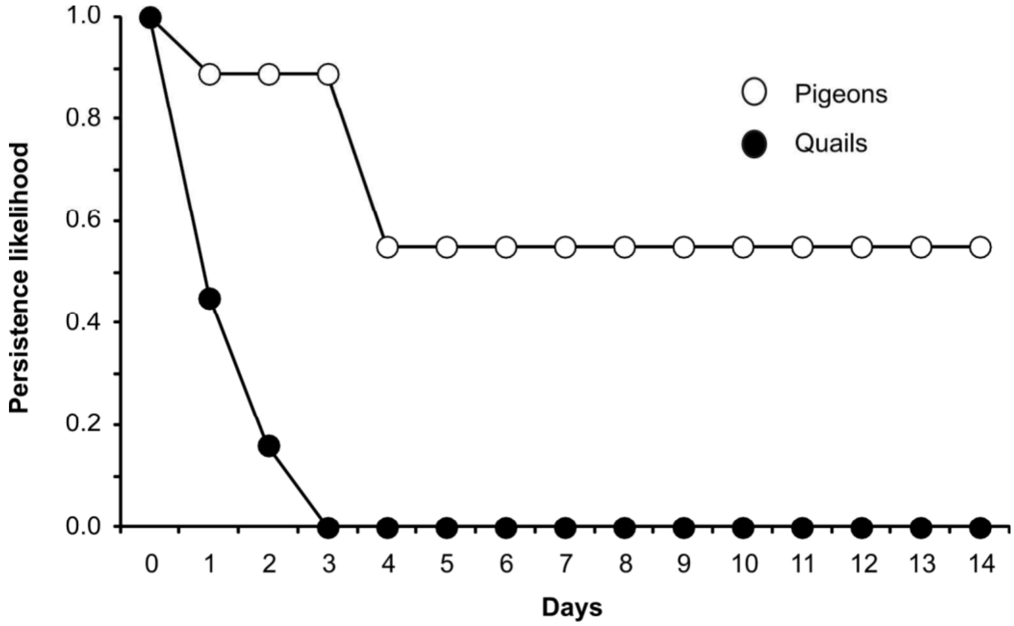

Figure 2. Kaplan-Meier disappearance functions for pigeon and quail carcasses experimentally deposited under wind farms and power line in the study area.
218x134mm (300 x 300 DPI)